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The embryological congruity of the human hip joint

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Summary

The embryology of the hip joint has been studied in a series of 32 embryos. The formation of the skeletal elements together with the capsule, glenoid, acetabular ligament, and ligamentum teres is followed until the definitive form is present. The congruity of the hip joint is established as soon as the joint cavity is formed.

Introduction

It is topical to talk of congruence or incongruence of the hip joint in relation to congenital dislocation. Much has been written about the cause and effect of incongruence. Congruence, however, appears to have been taken for granted. The purpose of this study was to investigate the establishment of hip congruence in the human embryo.

The distinction between embryo and fetus is arbitrary, the change occurring when the embryo possesses all the characteristics which may be recognised in later development. The beginning of the third menstrual month is accepted as a suitable division between the two stages[1]. At this time the embryo is 55–60 days postovulation and has a crown–rump length of approximately 30 mm.

Materials and methods

The study was performed by examining a series of sections of human embryos. A total of 32 embryos (64 hip joints) were examined, spread evenly between crown–rump lengths of 5 and 55 mm. This represents a postovulatory age of 32–90 days.

All embryos were fixed in 10% formalin solution and, where necessary, lightly decalcified with formic acid. They were sectioned in sagittal, coronal, and transverse planes, stained with haematoxylin and eosin, and mounted in Xam.

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Observations

ORIGIN OF LIMB BUD

The body of the embryo develops in a cephalocaudal direction. In the pre-somite period the embryo consists of a bilaminar disc of endoderm and ectoderm lying between the amniotic and yolk-sac cavities. The intraembryonic mesoderm differentiates from the ectoderm. Symmetrical growth of the paraxial mesoderm occurs on either side of the primitive streak

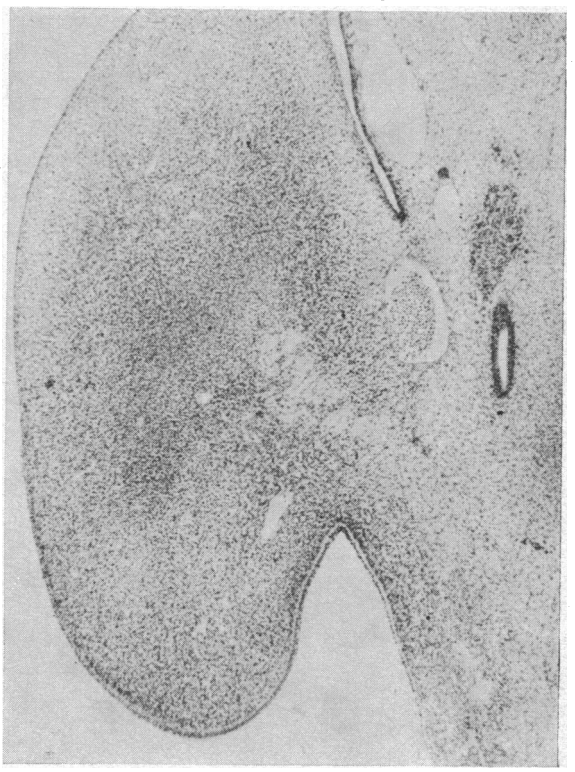

FIG. 1 *Coronal section of right hind limb of a 10-mm embryo (× 44). Cellular condensation can be seen in the region of the future hip joint.*

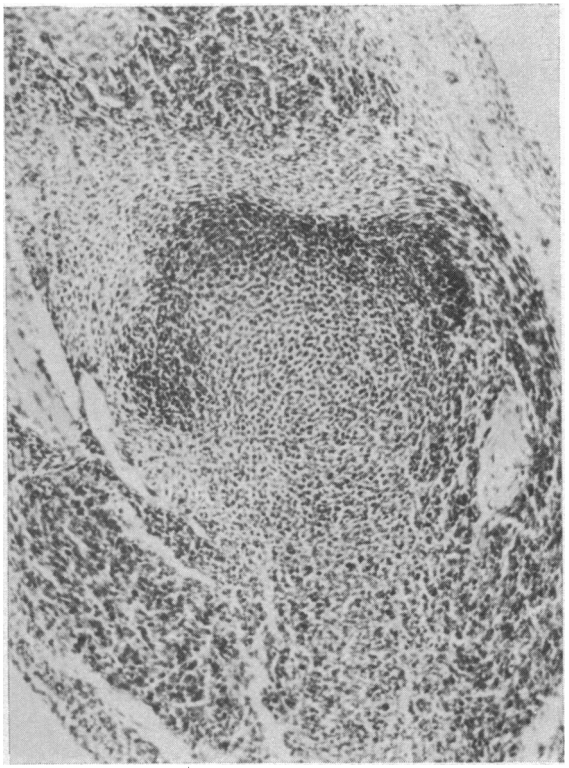

FIG. 2 *Coronal section of region of the future left hip in a 12.7-mm embryo (× 120). The region of the future joint cavity is shown as a halo of increased density encompassing an angle of 150° between the future pelvic and femoral primordia.*

and subsequently becomes divided into pairs of somites. Forelimb buds appear on the ventral side of the somites when the embryo reaches 3–4 mm. The hind limb buds appear shortly afterwards as truncated cones with bases applied to the anterolateral aspect of the embryo (Fig. 1). The bud contains mesoderm from within which all elements of the joint will subsequently develop. The distal end of the limb bud is formed by rapidly proliferating mesoderm which lays down prospective segments of the limb in proximodistal order. The proliferation is capped by a thin layer of ectoderm.

SKELETAL ELEMENTS

Review of the series of photomicrographs at between 5 mm and 16 mm (Figs 1–3) shows that a progressive condensation of cells occurs within the region of the future hip joint. The cells proximal and distal to this mesenchymal condensation pass progressively through to fibroblast, chondroblast, and osteoblast. Initially the cell is stellate or polymorphous, becoming progressively more round as the intervening intercellular spaces increase owing to the secretion of matrix.

Distal to the halo of mesoderm, which will form the joint cavity, that part of the limb bud which will form the femur begins to undergo differential growth. The cells in the region of the mid-shaft mature first, and as this process spreads proximally and distally it is joined by two additional centres in the region of the head and condyles of the femur. The femur then becomes outlined by smaller, more dense cells around the periphery which later acquire osteogenic properties. As progressive expansion from these three centres occurs the femur begins to take on its characteristic dumbbell shape (Fig. 3). At between 12.7 and 16 mm progressive angulation and narrowing at the neck of the femur can be seen to occur. By 25 mm bone salts are being deposited within

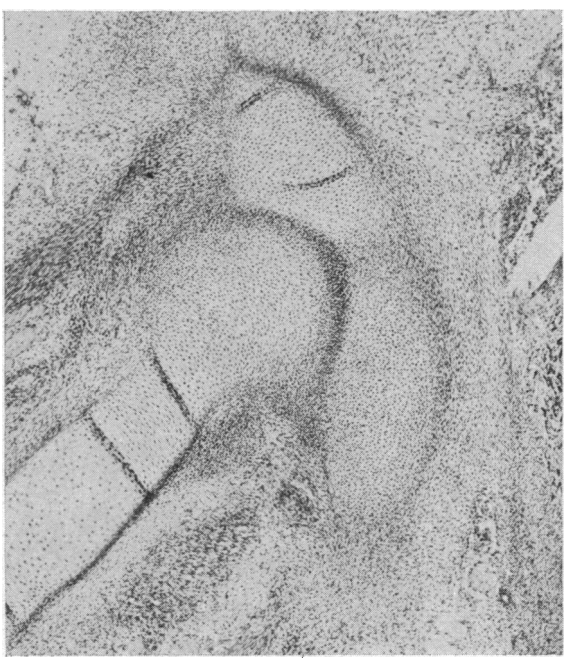

FIG. 3 *Coronal section of hip region of a 16-mm embryo (× 57). The pelvic and femoral primordia are seen separated by a more accurately defined region of mesenchymal condensation.*

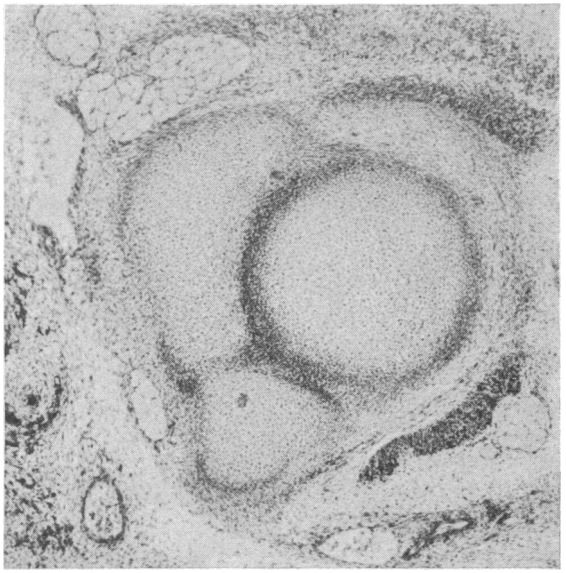

FIG. 4 *Transverse section of hip region in a 20-mm embryo* (× 50). *The interzone is beginning to appear at the anterior aspect of the junction between pelvis and femur.*

the degenerating cartilage at the centre of the shaft.

At 12.7 mm the os innominatum, together with the future acetabulum, appears as an area of diminished density proximal to the future joint halo.

At between 12.7 and 16 mm centres of chondrification appear in the ilium, ischium, and pubis, but their development lags behind that of the femur at all stages.

JOINT CAVITY

The appearance of the joint cavity is both a degenerative and a mechanical process. At 12.7 mm it is represented by an area of increased density within the mesenchyme (Fig. 2). As the pelvic and femoral components take on a more recognisable form the densely packed cells between them do not appear to have any specific orientation. Peripherally they merge imperceptibly with the surrounding tissues (Figs 3 and 4). At this stage the femoral head appears to be spherical.

At around 20 mm the dense zone becomes interspersed by a middle portion which is lighter in appearance. This results in a three-layered interzone (Fig. 5). The middle layer is directly continuous with the surrounding mesenchyme, while the two outer layers are continuous with the perichondrium of the pelvic and femoral components. This three-layered arrangement persists until spaces begin to appear in the central part of it at around 25 mm (Fig. 6). The joint space then extends around the head and down the neck of the femur. Initially the cavity is crossed by cellular strands, which are subsequently broken down by early movement within the joint. The spherical appearance of the femoral head appears to be lost during this period of differential growth.

LIGAMENTUM TERES

The ligamentum teres appears at between 20 and 25 mm as an orderly arrangement of greater cellularity within the region of the interzone in the position it will occupy in the fully formed joint. The individual cells appear as primitive fibroblasts with ovoid nuclei which merge with those of the transverse ligament inferiorly.

The ligament becomes longer and broader as the femur grows and becomes more adducted. As the joint cavity opens, the cells along the margin of the ligament split away from the neighbouring structures. The nuclei

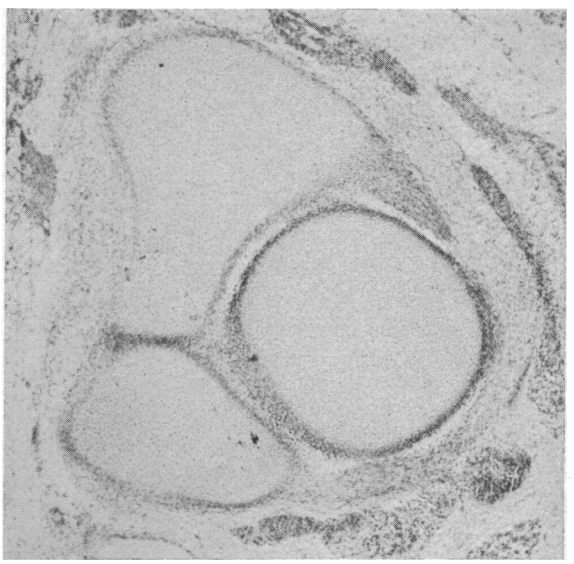

FIG. 5 *Transverse section of hip region in a 25-mm embryo* (× 42). *The interzone is well defined and the future ligamentum teres appears as an area of increased density within the interzone.*

FIG. 6 *Transverse section of hip joint of a 25-mm embryo (× 45). The joint cavity has opened in the central part but is still crossed by cellular strands. The glenoid labrum is well developed at this stage.*

of the constituent cells are orientated in the same direction as the ligament.

GLENOID LABRUM AND TRANSVERSE ACETABULAR LIGAMENT

The glenoid labrum appears as a cellular condensation at between 20 and 25 mm in the position it will occupy in the mature joint (Fig. 5). It consists of oval cells arranged concentrically around the rim of the acetabulum. At an early stage the mass of cells composing the glenoid is relatively great compared with that of the acetabulum (Fig. 6), suggesting that there is not a great extension of the cells with further growth but rather a progressive enlargement of the rim of the acetabular fossa pushing the glenoid out to its final position.

Before the appearance of the joint cavity or labrum the femoral head is encompassed by 150–165°. Once these structures have formed this figure is increased to 220–235°.

The cellular condensation for the transverse acetabular ligament develops in situ at around 30 mm and appears to originate from the interzone. By 33 mm it is well defined and consists of a dense cellular mass with the constituent cells orientated in the same direction as those of the glenoid.

CAPSULE

The fibrous capsule can first be identified in 20- to 25-mm embryos between the muscular primordia and the glenoid labrum (Fig. 5). With growth of the embryo the density increases in the region of the zona orbicularis and joint ligaments, and the capsule takes on the appearance of a definite entity when the embryo has a crown–rump length of 30 mm.

Discussion

This study confirms the fact that all the elements of the hip joint differentiate in situ from a single mass of mesoderm[2,3] and that by 55–60 days postovulation the joint resembles its final form. It also shows the necessity for the major components of the hip joint to be present before the formation of the joint cavity[4,5].

The joint cavity appears after 45–50 days in the central portion of the interzone and spreads peripherally around the head of the femur. Initially the cavity is crossed by cellular strands.

The concavity of the acetabulum is present at an early age, and congruence of the hip joint is established as soon as the joint cavity appears. Before the appearance of the cavity the femoral head is encompassed by 150–165°, but once the space has appeared and the labrum has formed this figure is increased to 220–235°.

Congenital dislocation usually occurs in the last 4 weeks of pregnancy. The embryological formation of the joint establishes early congruity, and incongruity can only occur after dysplasia or dislocation is established, allowing asymmetrical growth of the components to occur.

Initially the femoral head appears to be spherical, but some of this seems to be lost during the period of differential growth and formation of the joint cavity. Once the final form is established the head returns to its spherical shape[6].

None of the 64 joints examined showed any evidence of defective development.

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